REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
12-06-2012	Final Report	20-Sep-2010 - 19-Mar-2012

4. TITLE AND SUBTITLE
PHASE-CONTROLLED MULTI-TERAWATT FEMTOSECOND LASER (PCMTFL) FINAL REPORT

5a. CONTRACT NUMBER
W911NF-10-1-0491

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
611103

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
57661-PH-RIP.1

12. DISTRIBUTION AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
The Phase-Controlled Multi-Terawatt Femtosecond Laser (PCMTFL) is established as the major laser facility in the Townes Laser Institute at the University of Central Florida for study of high- intensity laser material interaction, laser propagation and ultrashort laser filamentation. Based on the existing laser system that was providing 35 fs pulses (25 mJ at 10 Hz
and 2 mJ at 1 kHz), it consists of an important upgrade of the latter. This upgrade is being performed at the present

15. SUBJECT TERMS
Final Report, PCMTFL

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UU	UU	UU	UU		Martin Richardson
					19b. TELEPHONE NUMBER 407-823-6819

Standard Form 298 (Rev 8/98)
Prescribed by ANSI Std. Z39.18

Report Title

PHASE-CONTROLLED MULTI-TERAWATT FEMTOSECOND LASER (PCMTFL) FINAL REPORT

ABSTRACT

The Phase-Controlled Multi-Terawatt Femtosecond Laser (PCMTFL) is established as the major laser facility in the Townes Laser Institute at the University of Central Florida for study of high- intensity laser material interaction, laser propagation and ultrashort laser filamentation. Based on the existing laser system that was providing 35 fs pulses (25 mJ at 10 Hz and 2 mJ at 1 kHz), it consists of an important upgrade of the latter. This upgrade is being performed at the present time by the Laser Development team inside the Laser & Plasma Laboratory. This choice was led by the importance of optimizing the specifications that can be obtained with the state-of-the-art COTS lasers, optics and crystals as well as the formation of students in CPA lasers.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Paper

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Khan Lim	0.00	
Joshua Bradford	0.00	
Andreas Vaupel	0.00	
Benjamin Webb	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**4**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Martin Richardson	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED	Discipline
Melody Carlson	0.00	
Eric McKee	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**2**	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:......	0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:......	0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):......	0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:......	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:......	0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
Matthieu Baudelet	0.00
Lawrence Shah	0.00
FTE Equivalent:	**0.00**
Total Number:	**2**

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Technology Transfer

PHASE-CONTROLLED MULTI-TERAWATT FEMTOSECOND LASER (PCMTFL)

Agency: US Army Research Office

Proposal Announcement / Number: AFOSR-BAA-2009-5

Contract Number: W911NF1010491

<u>*Principal Investigator: Martin Richardson, University of Central Florida*</u>

The Phase-Controlled Multi-Terawatt Femtosecond Laser (PCMTFL) is established as the major laser facility in the Townes Laser Institute at the University of Central Florida for study of high-intensity laser material interaction, laser propagation and ultrashort laser filamentation. Based on the existing laser system that was providing 35 fs pulses (25 mJ at 10 Hz and 2 mJ at 1 kHz), it consists of an important upgrade of the latter. This upgrade is being performed at the present time by the Laser Development team inside the Laser & Plasma Laboratory. This choice was led by the importance of optimizing the specifications that can be obtained with the state-of-the-art COTS lasers, optics and crystals as well as the formation of students in CPA lasers.

EQUIPMENT ACQUIRED THANKS TO THIS DURIP

The budget was redefined from the original proposal to adapt to the awarded funding ($155,596) and still fulfill the goals of providing a Phase-Controlled Multi-Terawatt Femtosecond Laser Facility for the DoD funded projects on filamentation in the lab.

The equipment actually purchase is listed as follow:

SYSTEM	NAME	MANUFACTURER	COST (USD)
Final amplifier pump laser	Powerlite DLS Series, Model 90	Continuum	113,725.00
Amplifier crystals	HEM Ti:Sapphire Laser Rod 90DE GT	Crystal Systems	7507.80
Dispersion management	HR Mirrors 700-900 nm	Tower Optical Corp.	3,140.15
	Pulse Compression Holographic Diffraction Grating PC 1400 120x140x20 NIR	Spectrogon	5,920.00
	Pyrex Plano-Convex Mirrors	Rocky Mountain Instruments	5,718.32
	Concave Pyrex Mirrors	Newport	1,060.79
Optomechanical structure	Mirrors and optomechanics	Edmund Optics	3,424.44
	Optomechanics	Newport	15,099.50
		TOTAL	**155,596.00**
		DURIP BUDGET	**155,596.00**

Adjustments to the revised budgets were made:

- The final amplifier pump from Litron was replaced by one with the same output (2 J at 532 nm in 6 ns) from Continuum for several reasons:

  - Continuum provides an optimum 2 Joules source for the pumping scheme of our upgrade up to 500 mJ. Litron can deliver at a lower price but, as explained by the company, their laser has been designed for lower energy and the reach of 2 J output but this system is at risk on a longer term.
  - Continuum is a US company, which allowed a cheaper installation of the system in the laboratory and a better service on a longer term

- The optimized design of the amplifier by the Laser Development team in the laboratory allowed the use of a single additional Ti:Sapphire crystal instead of two as planned in the revised budget. This allowed a large redistribution of the budget ($14492) for a better laser manufacturer and optimized dispersion management and optomechanical structure.
- The dispersion management has been extended to include the purchase of large area mirrors for the stretcher and compressor of the upgraded laser system (from Tower Optical Instruments, Newport and Rocky Mountain Inc.)
- The optimization of the optomechanical structure was possible thanks to the redistribution of budget (Additional mirrors being purchased additionally from Edmund Optics)

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<u>OUTCOMES AND RESEARCH PROJECTS</u>

Dr. Lawrence Shah, senior research scientist leading the Laser Development team inside the Laser & Plasma Laboratory of the Townes Laser Institute, has directed the implementation of the PCMTFL upgrade. This upgrade of the existing laser system has involved a large number of students, and contributed to their education:

- Melody Carlson (REU student in Summer 2011): optimization of the Acousto Optic Programmable Dispersive Filter for compensating the gain narrowing and amplifier design
- Waylin Wing (REU student in Summer 2012): implementation of the multi-pass amplifiers
- Eric McKee (Undergraduate student): implementation of the upgrade to be formed on the system for his projects in the DoD programs on filamentation
- Khan Lim (PhD student): implementation of the upgrade to provide advice as a future user and to be formed on the system for his projects in the DoD programs on filamentation
- Josh Bradford (PhD student): implementation of the upgrade as part of his formation in high power laser systems
- Andreas Vaupel (PhD student): design of the system and schedule of the upgrade as part of his formation on ultrashort laser systems
- Benjamin Webb (PhD student): lead student on the project. Design of the system and schedule of the upgrade as part of his formation on ultrashort laser systems

The project required the development of codes for the design of femtosecond laser systems:

- *Dispersion Design* (design of the stretcher and compressor, ray tracing)
- *Amplifier Design* (optimization of the number of passes, beam size, requirements for the beam size)

The completion of the upgrade is planned for August 2012. This will significantly aid in the education of existing students as well as the incoming students for Fall semester to be trained on the system for a full autonomy of operation. This laser, with its output of 500 mJ and 35 fs pulses at 10 Hz, will be the central facility for the study of filamentation:

- ***Engineered systems of filaments***

Multiple filamentation (MF) occurs when the laser power is significantly larger than the critical power Pcr of single filament formation (3.2 GW for a beam spectrally centered at 800 nm in air at atmospheric pressure). But to produce such multi-filaments pattern, the cylindrical symmetry has to be broken. The standard process that has been known for many years is that the multiple filaments are initiated by the input beam noise. However, it is possible to see noise-induced MF below this threshold if two mechanisms, one arresting the collapse and two breaking the symmetry, are input on the initial beam. Since noise is random by definition and thus the MF pattern would be different from shot-to-shot; however by modifying the polarization or the astigmatism of the beam, deterministic MF can occur. The engineering of multiple filaments in a deterministic pattern is then possible if:

1. the amplitude and/or phase noise in the laser pulse is controlled
2. the power in the beam is high enough

To fulfill these two parameters, the control of the spatial beam profile is crucial. This can be done thanks to the Diffractive Optical Elements (DOE). With the PCMTFL the study of engineering systems of filaments with different properties or in a burst mode will be more complete with a larger range of available intensities.

- ***Science of multiple filament formation***

The ARO-MURI “Light Filamentation Science” will profit from this upgraded laser system. And as mentioned above, the large amount of power in the laser beam will allow the control of the phase and the profile for a quantitative formation of multiple filaments, starting with two filaments and the repartition of the surrounding energy reservoir. Then the control of the phase of the beam by DOEs to create arrays of filaments and study the formation of “photonics lattices” for energy projection and propagation will be studied using the upgraded laser.